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Capítulo 1

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Abstract

The formation of stimulus equivalence relations for three-member three classes was assessed by employing a complete versus an incomplete baseline training. In Experiment 1, symmetry and transitivity test trials for the assessment of equivalence class formation were intermixed in the same experimental phase. In Experiment 2, symmetry was tested first and then transitivity was tested. With a complete baseline high scores in symmetry and transitivity were obtained, but with an incomplete baseline symmetry emerged only for the trained baseline relations, while transitivity did not emerge. Data suggests that symmetry exclusively depended on the baseline, and that it is a necessary but not sufficient condition for the emergence of transitivity, and that the emergence of a single class might not be possible, but rather it requires contrast with other classes.

Key words: Stimulus equivalence, matching to sample, baseline, symmetry, transitivity.

Introduction

The formation of stimulus equivalence classes has been one of the main experimental paradigms employed in the field of the experimental analysis of behavior for the study of the so-called symbolic behavior (Sidman, 1994; Wilkinson & McIlvane, 2001). "Stimulus equivalence" is evidenced when some participants learn a baseline of arbitrary conditional discriminations, and then they show emergent responses that show the properties of a mathematic equivalence relation: reflexivity, symmetry, and transitivity (Sidman & Tailby, 1982; Green & Saunders, 1998). For example, a participant learns to select the comparison stimulus B1, rather than the stimuli B2 or B3, when, and only when, the sample stimulus A1 is present. Likewise, he/she learns to select B2 and B3 conditionally to the presence of either the A2 or A3 sample stimuli, respectively. Reflexivity consists in the relation of each stimulus to itself, and it is evidenced when, for example, the participant selects the comparison stimulus A1 rather than A2 or A3, when this same stimulus is presented as the sample. Symmetry consists in the reverse of the sample-S+ baseline trained relations, and it is observed when the participant selects, for example, stimulus A2, rather A1 or A2, in the presence of B2 as a sample stimulus. Finally, transitivity consists in the display of emergent relations among stimuli that were not related to each other in the baseline, but which were both related to some common stimulus. So, if the participant also learns to select the stimulus C3 in the presence of sample A3, then she might relate B3 and C3 to each other, despite the fact that no trial in the baseline did it. A participant displaying such emergent responding is said to have established some classes of stimulus equivalence. In our particular example, the A1B1C1, A2B2C2, and A3B3C3 stimulus classes would emerge.

An important property of these classes is the observation of transfer of stimulus functions among those stimuli belonging to the same class. For instance, if stimulus A2 has acquired the function of conditioned reinforcement, then this function will transfer to the B2 and C2 stimuli, without any additional training, insofar as the three belong to the same stimulus equivalence class (e.g., Hayes, Kohlenberg, & Hayes, 1991). Accordingly, transfer has been observed with respondent functions (e.g., Dougher, Augustson, Markham, Greenway, & Wulfert, 1994), self-discrimination response functions (e.g., Dymond & Barnes, 1994), and contextual control (e.g., Pérez-González & Serna, 2003), among other stimulus functions.

Further, stimulus class formation has been readily observed in human adults (e.g., Eilifsen & Arntzen, 2009), human children (e.g., Sidman, Kirk, & Willson-Morris, 1985), and individuals with developmental disabilities (e.g., Haring, Breen, & Laitinen, 1989; Sidman, Cresson, & Willson-Morris, 1974). However, the establishment of equivalence classes has not been clearly evidenced in non-humans (e.g., Sidman et al., 1982; Dugdale & Lowe, 2000), unless the emergent response was explicitly taught previously (Schusterman & Kastak, 1993). Thanks to these properties, the experimental analysis of this phenomenon has become a paradigm for the study of symbolic behaviors, especially those involved in linguistic relations, under the assumption that words and their referents can be said to be in equivalence relations to each other (Sidman, 1994).

The conditional discriminations required for the establishment of equivalence classes are frequently trained or tested in the matching to sample (MTS) format, in which participants have to select among some comparison stimuli conditionally to the presence of a particular sample stimulus, as in the examples given above. In training, the MTS format establishes both positive and negative relations among samples and comparisons. Positive (or 'select') relations are those between each sample stimulus and the comparison stimuli whose selection is reinforced in their presence (sample-S+ relations). Negative (or 'reject') relations are those between each sample and the comparison stimuli whose selection is *not* reinforced in their presence (sample-S– relations) (Carrigan & Sidman, 1992; Johnson & Sidman, 1993; McIlvane, 2013; Stromer & Osborne, 1982).

In the standard MTS procedure, all the positive within-class relations and all the negative between-class relations among the stimuli of the experimentally predefined classes are explicitly and simultaneously trained. A typical standard-MTS trial, for example, would be of the type A1-B1/B2, B3 (corresponding to sample-S+/S–, S– stimuli, respectively). It has been demonstrated that the likelihood of equivalence class formation is high when this procedure is used (e.g., Carr, Wilkinson, Blackman, & McIlvane, 2000; Smeets, Barnes-Holmes, & Cullinan, 2000). Other procedures can be used, though. In an "altered MTS procedure," the same positive within-class relations are trained as in the Standard MTS

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procedure, but the negative relations are trained with stimuli which do not belong to any class. For example, a typical trial would be A1-B1/X1, X2, wherein the X stimuli are not positive to *any* sample in any trial. The likelihood of equivalence class formation with this altered MTS procedure is very low (Plazas & Peña, 2016; Plazas & Villamil, 2016a, b). A third procedure, in between the standard and altered MTS procedures, is what we have called the “semi-standard MTS” procedure, in which each training trial establishes one negative between-class relation, and one negative relation with an X stimulus, as in the trial A1-B1/B2, X1. Plazas and Peña (2016) found that the likelihood of establishing equivalence relations with the semi-standard procedure was as high as that of the standard procedure.

The finding of similar probabilities of equivalence class formation with the semi-standard MTS procedure suggests that the establishment of equivalence classes is possible with an incomplete set of relations, as compared with those of the standard MTS procedure. If this is indeed the case, it could be expected that equivalence relations might emerge from an incomplete baseline. The establishment of three three-member stimulus classes, as depicted in the examples above, typically requires the training of six baseline trials, as shown in the upper panel of Figure 1. In the present study, our interest was to assess the emergence of the same number of classes, but with an incomplete baseline, containing only four of the six baseline relations. Complete baseline training involves three pairs of AB and AC conditional relations, one pair for each of the classes 1, 2, and 3. In our modified procedure, some participants were trained with an incomplete baseline, consisting of only one pair of AB and AC relations for class 1, one relation AB from class 2, and one AC relation from class 3 (see upper panel of Figure 1). If the probability of equivalence class formation with the incomplete baseline is similar to that with a complete baseline, then two important conclusions could be made. First, the phenomenon of equivalence class formation might be more “productive” than usually admitted, in the sense of the amount of relations emerging from those relations that are trained. Second, this might suggest that the formation of equivalence relations is guided by higher-level processes, rather than the establishment of some particular conditional sample-S+ and sample-S– relations, which might compensate for the absence of some trained relations in the incomplete baseline procedure.

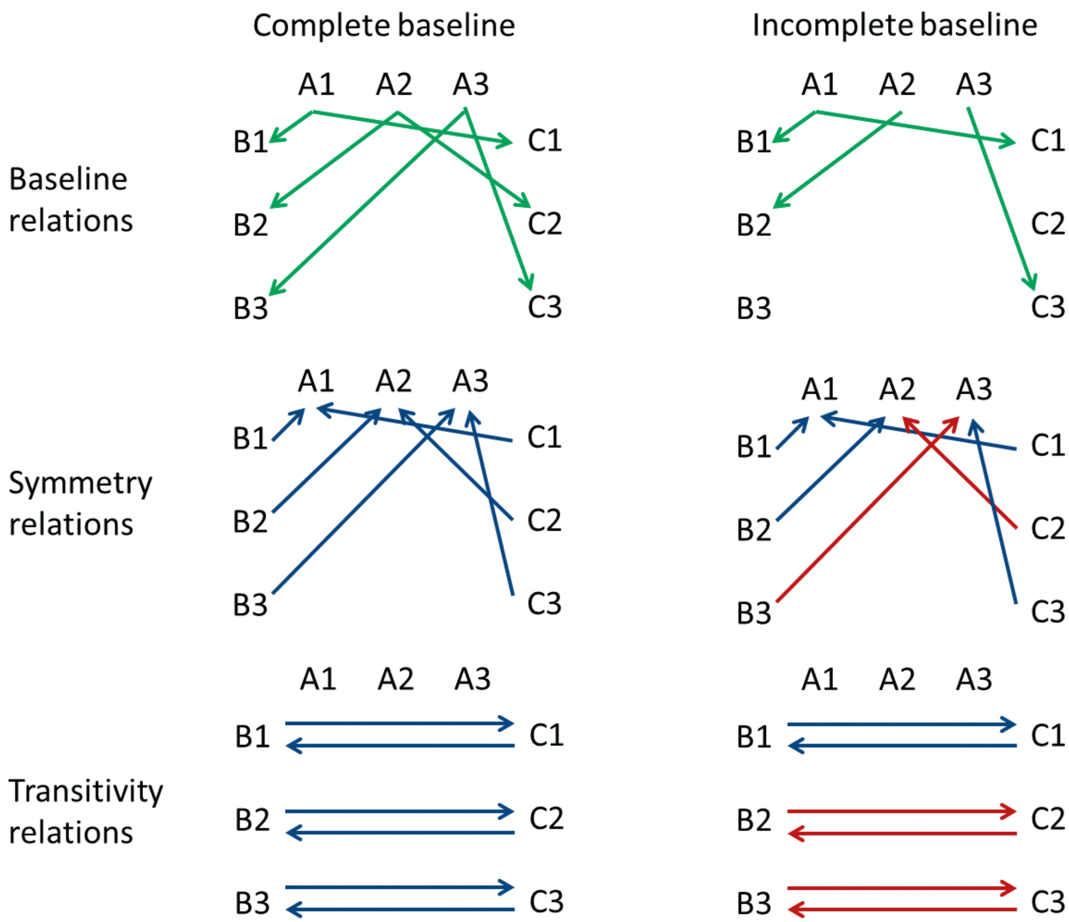

Figure 1. Training and test trials in the complete-baseline and incomplete-baseline procedures. The direction of the arrow indicates the direction of the sample-S+ relation. Green arrows correspond to relations explicitly trained. Blue arrows correspond to emergent relations with proper antecedents in the baseline. Red arrows are emergent relations without proper antecedents in the baseline.

Experiment 1

Method

Participants. Sixteen first-semester psychology students participated in this experiment. They were randomly assigned to Groups 1 and 2, each one composed of eight participants. Their ages ranged from 16 to 21 years old (M = 18.3, SD = 1.54). Only one participant was male, and he was in Group 2. They signed an informed consent form, or had one signed for them by one of their parents if they were minors, before the beginning of the experiment. Participants obtained some academic credits in the "Introduction to Psychology" course for their participation.

Setting, apparatus, and stimuli. The experiment was carried out in the Human Behavior Laboratory of the Fundación Universitaria Konrad Lorenz. Participants were placed in front of a computer, separated by modules to avoid observing the performances of others. Presentation of the stimuli, and recording of participant responses were controlled by a program designed in Visual Basic. Stimuli were non-Latin letters, in black lines over a white background (see Figure 2). Participants received auditory instructions by way of headphones before each phase, describing what they were expected to do.

Figure 2. Stimuli employed in the study.

In each trial, a sample stimulus was presented in the center-top area of the screen, and participants had to click on it for three comparison stimuli to appear in a row in the bottom area of the screen. Then, participants had to select one of the comparison stimuli by click on it. Throughout the first three phases, the selection responses of the participants were followed by auditory feedback. If the response was correct, they would hear a "ta-da" tone, but if it was incorrect, they heard a "chord" tone. Participants were instructed about the functions of the two tones before the beginning of the first phase.

Design. A two-groups design with only post-test was used in this experiment. Participants from Group 1 were trained with a complete baseline, while participants from Group 2 received incomplete baseline training. The upper panel of Figure 1 presents the structure of the training relations for both groups. Participants of both groups were then tested for the establishment of equivalence relations through the testing of symmetry and transitivity emergent relations (see middle and lower panel of Figure 1).

Procedure. The experiment consisted of five phases. The first four phases established the baseline relations, employing a standard procedure. Phase 1 trained the AB relations, three for Group 1 and two for Group 2. Participants from Group 1 were presented with blocks of 15 trials, while participants from Group 2 were presented with blocks of 10 trials (each trial type five times). A mastery criterion of 100% in a single block was in place in order to advance to the next phase, or else the phase was repeated. Phase 2 trained the AC relations, again three for Group 1 and two for Group 2, with the same amount of trials by block for each group, and the same mastery criterion. Phase 3 intermixed the training trials of the two previous phases in blocks of 24 trials and with a mastery criterion of 23/24 correct responses for Group 1, and in blocks of 16 trials and a criterion of 15/16 correct responses for Group 2. Each of the participants' responses throughout these first three phases was followed by auditory feedback. Phase 4 presented 12 of these training trials for Group 1, and 8 for Group 2, with a mastery criterion of 100%, but without providing any feedback. This phase was to serve as a learning test, and also familiarized participants with the absence of feedback in the testing phase. If a participant did not meet the criterion in this phase, she was returned to the Phase 3. Phase 5 presented *testing* trials, intermixed among baseline trials, all without any feedback. There were 12 symmetry trials, 12 transitivity trials, and 12 baseline trials for both groups in this phase. The middle and lower panels of Figure 1 depict the relations tested in these trials, which were the same for both groups.

Results

Table 1 shows results regarding the range, mean, and standard deviation of the number of blocks required by participants from Groups 1 and 2 in the baseline acquisition phases. In general, participants from Group 1 required more training blocks for the acquisition of the baseline. The sole exception was a participant from Group 2 who needed 52 blocks in the first phase, while the rest of the participants from this group needed between three and seven blocks. However, in none of these phases a statistically significant difference was observed between the groups. As the phases advanced, the number of blocks required to master the criterion decreased. All participants from both groups demonstrated acquisition of the baseline relations at the first attempt in phase 4.

Table 1 Statistical Analyses of the Number of Blocks Required for Baseline Acquisition in Experiment 1

	Group 1			**Group 2**		
	Range	*M*	*SD*	*Range*	*M*	*SD*
Phase 1	3-22	8.4	6.0	3-52	11.3	16.6
Phase 2	2-15	4.9	4.4	1-5	3.1	1.6
Phase 3	1-8	2.1	2.4	1-3	1.8	0.7
Phase 4	1-1	1	0	1-1	1	0

Figure 3 depicts the mean percentages of correct responses by group for each of the symmetry and transitivity test trials. We took a score of greater than or equal to 75% of correct responses as the criterion for high performance. Participants who trained with a complete baseline (Group 1) displayed high performances in each symmetry relation, while participants trained with an incomplete baseline (Group 2) only displayed high performance in those symmetry trials for which their corresponding baseline trial was explicitly trained. Participants from the complete baseline group achieved the criterion for 5/6 transitivity relations, while participants from the incomplete baseline displayed low performance in all transitivity relations. It should be noted that for Group 2 the scores in the C2B2 and B3C3 transitivity trials were equal to or slightly above 0%, which indicates not inaccurate performance, but rather a systematic selection of a different comparison stimulus as compared to that pre-experimentally established as correct for these transitivity trials. These participants selected the B3 comparison stimulus when C2 was the sample, and also selected C2 when B3 was the sample 65.3% of the time.

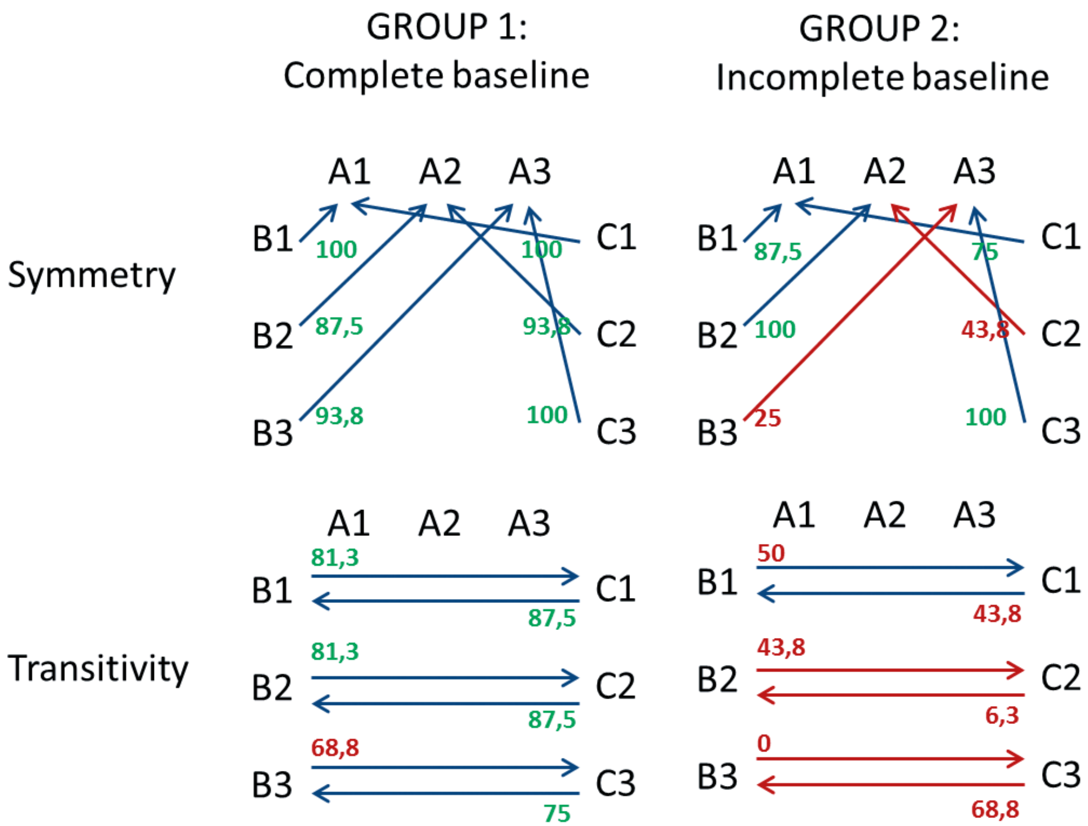

Figure 3. Results of Experiment 1. Arrow colors and directions correspond to those in Figure 1. Numbers correspond to the mean percentage of correct responses. Numbers in green correspond to scores equal to or above 75%, and red numbers are scores below 75%.

Discussion

Equivalence class formation was readily obtained with a complete baseline, but it was not with an incomplete baseline. Results from the group trained with an incomplete baseline show that symmetry emerged only for relations explicitly trained in the baseline, and independently of high scores in transitivity, which suggests that symmetry performance only depends on the baseline trained relations. Transitivity did not emerge in any of the classes for Group 2, despite the fact that the baseline prerequisites for the emergence of Class 1 were trained. These results suggest that the emergence of a single class in isolation is not possible, and the emergence of at least two contrasting classes is required. Results do not support the hypothesis that equivalence relations can be established with an incomplete baseline, and suggest that the *complete* baseline contains the minimal prerequisites for the formation of equivalence classes.

In transitivity trials with stimuli B3 or C2 as the sample, participants from Group 2 tended to select the comparison stimuli C2 and B3 respectively. B3 and C2 were 'undefined' stimuli, that is, stimuli not positively related in the baseline. Thus, participants from the incomplete baseline group related each undefined stimuli to the other in these transitivity trials. This performance is called *exclusion*, and it is a well-known phenomenon in the experimental literature with human subjects (e.g., Dixon, 1977; McIlvane et al., 1987; Wilkinson & McIlvane, 1997), and even with nonhumans (e.g., Beran, 2010; Kaminski, Call, & Fischer, 2004). In consequence, it can be argued that in these types of trials for participants trained with the incomplete baseline, exclusion responding probably interfered with the expected selections according with the classes pre-experimentally defined.

In this experiment, symmetry and transitivity relations were tested in the same phase, intermixed among themselves. Alternatively, some studies have employed a simple-to-complex format, in which symmetry is independently tested first, and then transitivity is tested, and in general they have found that participants have higher scores in these tests (Adams, Fields & Verhave, 1993; Fields, Adams, Newman & Verhave, 1992; Smeets, Barnes & Roche, 1997; Smeets, Dymond & Barnes-Holmes, 2000). It is possible that employing a simple-to-complex format in the testing for emergent relations in this study might lead to higher scores in symmetry and transitivity, particularly for the group with an incomplete baseline. This format might lessen the interference effect of the exclusion responding in the transitivity trials with undefined sample stimulus. Experiment 2 was carried out in order to assess this suggestion.

It is possible that employing a simple-to-complex format in the testing for emergent relations in this study might lead to higher scores in symmetry and transitivity, particularly for the group with an incomplete baseline.

Experiment 2

Method

Participants. Sixteen first semester psychology students participated in this experiment. They were randomly assigned to Groups 3 and 4, each consisting of eight participants. Their ages ranged between 16 and 23 years old (M = 18.3, SD = 1.7). Only one male was part of the sample, and he was in Group 4.

They had the same conditions of informed consent and reward as participants of Experiment 1.

Setting, apparatus and stimuli. This experiment was carried out in the same laboratory, with the same computers, and stimuli used for Experiment 1.

Design and procedure. The design of this experiment was the same as that of Experiment 1. Participants in Group 3 were trained with a complete baseline, while participants in Group 4 were trained with an incomplete baseline; they were then tested for symmetry and transitivity, as evidence of equivalence relations formation. The first four phases had the function of baseline acquisition, and they had exactly the same structure for Groups 3 and 4 as that for Groups 1 and 2 respectively in Experiment 1. The only difference between this experiment and the previous one was that symmetry and transitivity performances were tested separately. Symmetry was tested first, in Phase 5, which consisted of a single block of 24 trials, twelve for baseline trials and twelve for symmetry trials. Phase 6 had twelve baseline trials, and twelve transitivity trials. In these two phases, no response was followed by feedback.

Results and Discussion

Table 2 shows the statistical analyses of the number of blocks required by participants from Groups 3 and 4 to meet the criteria of the baseline acquisition phases (which were the same as in Experiment 1). In general, participants trained with an incomplete baseline required less blocks than those trained with a complete baseline, but a statistically significant difference was not observed for any of these phases.

Table 2 Statistical Analyses of the Number of Blocks Required for Baseline Acquisition in Experiment 2

	Group 3			**Group 4**		
	Range	*M*	*SD*	*Range*	*M*	*SD*
Phase 1	1-15	5.4	4.4	1-7	3.8	1.9
Phase 2	2-5	3.4	1.1	2-4	2.6	0.9
Phase 3	1-3	1.8	0.9	1-4	2.0	1.3
Phase 4	1-2	1.1	0.4	1-1	1	0

Figure 4 depicts the mean number of correct responses in the symmetry and transitivity trials for participants from Groups 3 and 4. In general, results were very close to those of the Experiment 1. Participants trained with a complete baseline had high scores in all the symmetry and transitivity relations. Participants trained with an incomplete baseline had high symmetry scores only in those relations for which the respective baseline relation was explicitly trained. Performance in all transitivity trials was low. Scores in those transitivity trials in which either the B3 or C2 stimuli was the sample stimulus were close to 0% and in 59.4% of these the participants chose the undefined stimulus. As a consequence, exclusion responding apparently prevents the emergence of transitivity relations according to the pre-experimentally defined classes. The separate testing for symmetry and transitivity relations did not improve the scores in these relations for participants trained with the incomplete baseline, and the differences observed in the Experiment 1 between both groups in the establishment of equivalence relations was also replicated in this experiment.

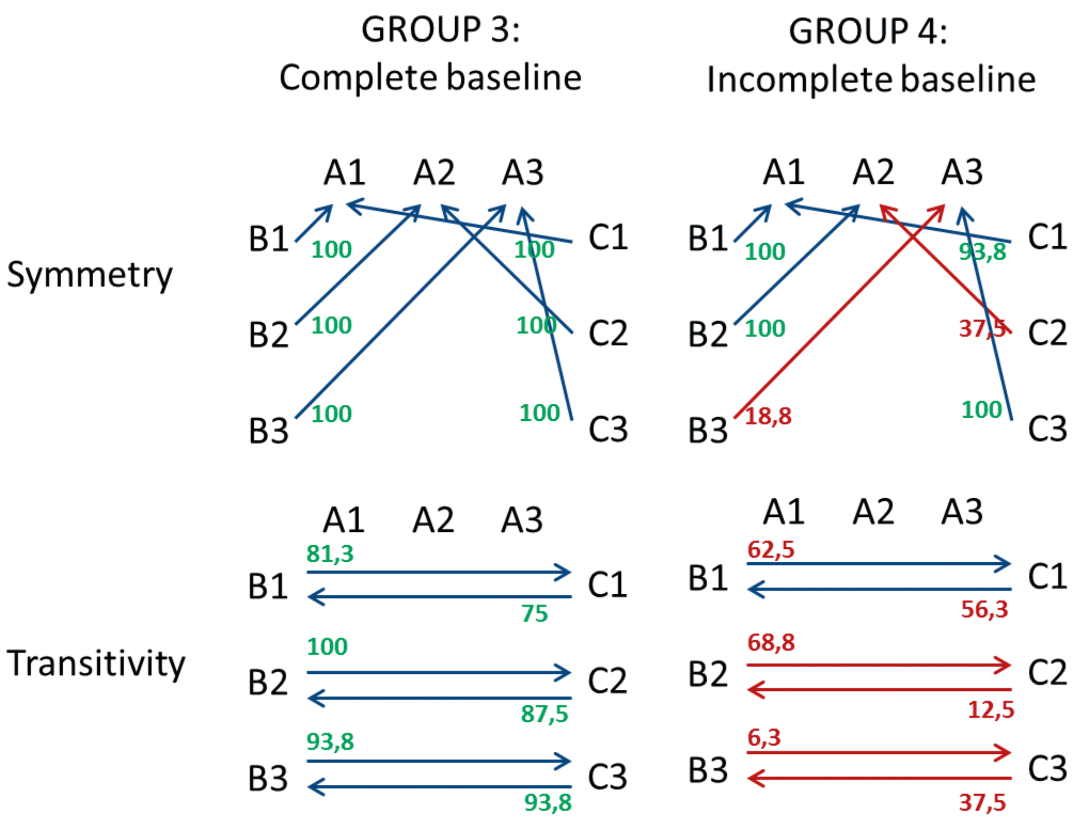

Figure 4. Results of Experiment 2. Colors of arrows and numbers correspond to those in Figure 2.

General Discussion

The two experiments in this study show that the establishment of three 3-member equivalence classes is not possible with an incomplete baseline of only four relations, consisting of the AB and AC relations for Class 1, only the AB relation for Class 2, and the AC relation for Class 3. These results suggest that equivalence class formation is strongly dependent on the positive and negative conditional relations trained in the baseline, and no higher level behavioral process occurred to fill the gaps left by those relations not being included in the incomplete baseline. Symmetry responding was highly dependent on the baseline-trained relations. These results confirm some evidence suggesting that symmetry depends exclusively on the positive (sample-S+) conditional, trained relations (Plazas & Cortes, 2017; Plazas & Maldonado, 2018; Plazas & Villamil, 2016a, b). In the symmetry test trials in which the B3 or C2 stimuli were sample stimuli, participants failed to select the A3 or A2 comparison stimuli respectively. These selections were not expected by exclusion, insofar as the A3 and A2 stimuli had been related to the C3 and B2 stimuli respectively in the baseline. Given that the symmetry test phase presented the BA and CA stimuli intermixed, and that stimuli A3 and A2 were defined, participants had no base to select these stimuli when B3 or C2 were presented.

We anticipated that the training of the A1B1 and A1C1 relations would be enough base for the emergence of relations between the stimuli B1 and C1, and that this might allow for the emergence of the other transitivity relations. However, the first result was not obtained, and thus there is no base for the late results. The absence of a relation between the B1 and C1 stimuli suggests that the transitivity relations require more than the relations between these stimuli and some common stimulus. In contrast to symmetry responding, which seems to depend only on the sample-S+ trained relations, some studies have also shown that transitivity depends too on the between-classes sample-S– trained relations (Plazas & Peña, 2016; Plazas & Villamil, 2016a, b, 2018). However, these relations also were trained in the present study. The B3 and C2 stimuli which were not positively related to another one in the baseline were, nevertheless, negative comparison stimuli for the A1 sample stimulus. Given that these stimuli were not positively related in the training, they did not belong to alternative classes in regard to Class 1. It is possible that, if at least one of these stimuli had been positively related, for instance C2 to A2, then accurate transitivity responding for Class 1 would be observed, and likewise for Class 2. This suggests that transitivity responding and the formation of stimulus classes cannot be observed for a single class in isolation, and that the emergence of at least two classes is required for stimulus equivalence relations to be established.

Participants trained with the incomplete baseline mostly related the B3 and C2 stimuli in the transitivity trials in which any of these two stimuli was the sample stimulus. As pointed out before, this is an instance of exclusion responding, given that both stimuli were undefined stimuli, insofar as they were not positively related in training. As a consequence, exclusion responding interfered with the transitivity responding that was expected by the pre-experimentally defined classes. This had a negative effect on the emergence of correct transitivity responses among the stimuli of classes 2 and 3. If transitivity responding and equivalence class formation do not emerge for a single class in isolation, then exclusion performances might also have interfered with the emergence of Class 1. It is possible that by introducing transitivity test trials in which B3 or C2 would be sample stimuli, but preventing exclusion responding in some way, for example, by not including these stimuli among the comparisons, more accurate responding in accordance with the predefined classes would be observed, and that the emergence of Class 1 would be more likely. Further research is needed to assess this hypothesis and to further understand the establishing of the minimal training conditions for the emergence of equivalence relations.

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